

EXPERIMENTS ON THE AESTHETIC
OF LIGHT AND COLOUR

SECOND ARTICLE

SPECTRALLY PURE COLOURS IN BINARY COMBINATIONS

BY

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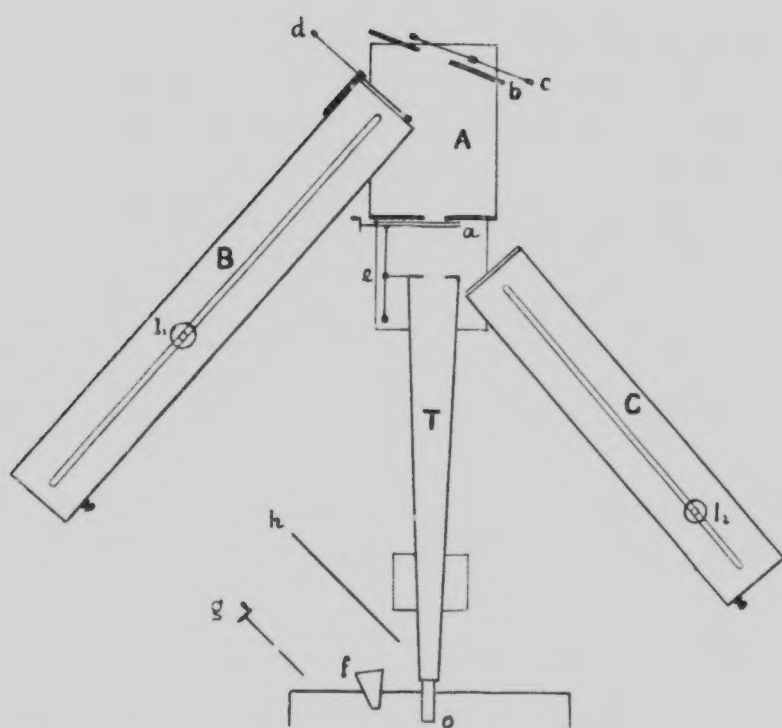


PLATE A

SPECTRALLY PURE COLOURS IN BINARY COMBINATIONS

In the fourth number of the Psychological Series of University of Toronto Studies¹ was published an article containing the results of experiments on the æsthetic value of colour combinations. The colours used in those experiments were pigment colours, and the surfaces were the same in shape and of equal size. In view of the importance of the relative proportions of the surfaces, it was thought desirable to conduct a second series of experiments, in which it might be possible to vary the size of the surface. This phase of the problem was investigated during the years 1899-1900 and 1900-01, in room 16 of the Psychological Laboratory².

The apparatus and method employed were entirely different from those used in the former experiments. The apparatus was that described by Dr. W. B. Lane, in an article entitled "Space Threshold of Colours and its Dependence upon Contrast," published in No. 1 of the Psychological Series of University of Toronto Studies. As Dr. Lane's article contained an illustration and a detailed explanation of the apparatus, we shall confine ourselves here to a short description of it, particularizing the changes which our experiments necessitated, and illustrated by a schematic representation (Plate A) which gives a view of the apparatus from above.

In the plate, A is the central table; upon the front edge is erected the upright with the micrometer diaphragm *a*, of which Figure 2 in Dr. Lane's article gives an illustration. At the other end of this table, in a somewhat slanting position, there is another upright *b*, through which is visible one of the coloured pigments arranged on a movable disc *c* behind it. The pigment is illuminated by the electric light *l* adjustable to various distances in box B. The rays of this light have to pass through one of the combinations of gelatines which are arranged in the form of a revolving wheel *d* at the front of the box. The com.

¹ Vol. I., p. 203.

² See plan of the Laboratory in Vol. I.

binations of absorbing media are selected in such a way that light which has passed through one of them and is then reflected from the corresponding part of c^1 will be confined to a very limited part of the spectrum, thus furnishing light just as pure as if a certain region of the spectrum itself had been taken, but not limited in intensity and space extension. This light is then seen through the observation tube T, and through the aperture of the diaphragm a , whilst the opaque parts of the latter are covered with another pigment paper illuminated in an analogous manner by means of l_2 in box C.

At the end of box C is inserted a gelatine preparation as required by the ground colour. Since the ground colour remains constant during a whole series of experiments there is no need for the gelatine preparations to be arranged in the form of a disc. They are identically the same as those for the other box but they have the form of squares of the same size as the opening of the box. The observation tube T is attached to the moving part of the diaphragm a by a lever arrangement e in such a manner that its end moves with half speed. This keeps the middle part of the diaphragm always in the centre of the field. At the ocular end of this tube o a large screen shuts off the eye of the observer from all other parts of the apparatus. The eye-piece f , the graduated slit g , and the screen h , render it possible to compare the light seen through the tube with real spectral light generated by a lantern and spectral apparatus in an adjoining room (the first annex of Room 16). Through the observing tube can now be seen the two surfaces, the ground colour on the diaphragm, illuminated by l_2 , and through the opening of the diaphragm the colour to be combined with the ground colour, illuminated by l_1 . There were twelve colours in all which could be changed by a revolution of discs c and d .

The intensity differences were eliminated in the following way: The distances of lights l_1 and l_2 were gradually changed until the two surfaces appeared of equal brightness.¹ The correct distances of the lights having been found, they were marked on the sliding scales of boxes B and C. The ground colour, which

¹ See also Dr. Lane's article.

² See also Dr. Lane's article, pp. 23-24.

was constant through a series of trials, was given, by the position of I_2 , the intensity which the same colour had as seen through the diaphragm. It is easily possible by adjusting the lamps to arrange the intensities in such a manner that the ground colour and the transmitted colour form one uniform surface. It may be remarked that we succeeded in getting the two colours to look so exactly alike, that, although there is a distance of about two feet between the two surfaces, the observer at the end of the tube could not possibly detect the slightest deviation from a uniformly coloured surface, no matter what was the aperture of the diaphragm revealing the transmitted colour.¹ And, indeed, before each series of trials this impossibility of distinguishing the surfaces was made the criterion for the correctness of the intensity of the ground colour.

We next come to the method of procedure. The room was darkened and the observer placed himself at the end of tube T where he saw first the ground colour only, illuminated as described. Then by turning the micrometer handle there was made to appear in the centre one of the other twelve colours. This colour appeared first as a little spot. As it increased and rose above the characteristic space threshold² the observer stated whether the combination was pleasant, and whether it became more or less pleasant with the change in the comparative proportions of the two components; for as the transmitted colour increased the ground colour decreased until finally only a small border of it was left. The observer, who had now seen all the possible relations in size of the two components, was asked to decide if the combination on the whole was very pleasant, pleasant, indifferent, or unpleasant. This was not

¹ Miss Baker calls the qualities obtained by the above described method "spectrally pure," meaning thereby that a limited region of the spectrum is selected without admixture of light from other regions. I regard this as the only correct way of using the term "spectrally pure," which admits of degrees. If by a "pure" spectrum is understood a spectrum which has at every point light of *one* wave-length only, then a "pure" spectrum is impossible, as I have shown elsewhere. And even if such a spectrum could be obtained it would be absolutely impossible to produce one of its colour-qualities homogeneously on a surface. Much of what has hitherto been said and is generally accepted with reference to the "purity of spectral colours" owes its prestige to errors of thought, concealed behind abstruse terms and complicated formulas.—*A. Kirschmann*.

See Dr. Lane's article.

always an easy judgment to make, for in some combinations the affective character varies very much even to the extent of being unpleasant at one comparative proportion and very pleasant at another. This estimation had no direct bearing on the real problem for which this investigation was undertaken, namely that of the influence of the relative size; the judgment was taken to see if under entirely different conditions the results of our former experiments would be corroborated. By a comparison of curves 1-12 with curves I-XXIV of our former article to which attention will be more fully called further on, it will be seen that the results of the two series of experiments do not essentially differ.

As we reversed the proceeding, the transmitted colour becoming gradually less and less, the observer stated where the combination was most pleasant or, if unpleasant, where it was comparatively most pleasant. Each full turn of the micrometer handle changes the mutual space relations between the diameters of the two colours by the twentieth of an inch. In doubtful cases to secure a definite decision the procedure was repeated, if necessary, several times. In this way all the eleven colours were treated successively with the same ground colour. A whole series of trials was taken at one sitting. The same procedure was repeated with each of the colours as ground colour. A spectroscopical analysis of the colours used will be found on the following page.

There were in all $12 \times 11 = 132$ combinations. In each series of trials there were 25 observations, giving $132 \times 25 = 3300$ judgments of very pleasant, pleasant, indifferent or unpleasant. Of these twenty-five observations, eleven were made by regular observers who took the whole series, and in several cases repeated the experiments. Many took about half the series, and in each individual series there were a few casual observers. It is only fitting here to acknowledge our great obligations to all these ladies and gentlemen, who, often at a great inconvenience to themselves, were so faithful in their appointments and manifested such an interest in the problem.

For the phase of the problem which refers to the size of the components there were 3300 complete transitions from the

SPECTROSCOPICAL ANALYSIS OF THE COLOURS USED.

Name of Colour.	With Narrow Slit.		With Wide Slit.	
	Visible part of spectrum in $\mu\mu$	Region of greatest intensity in $\mu\mu$	Visible part of Spectrum in $\mu\mu$	Region of Greatest intensity in $\mu\mu$
Red.	665(?)—592.5	635—610	672.5(?)—580	657.5—615
Orange-Red.	622.5—582.5	612.5—592.5	635—580	622.5—592.5
Orange.	607.5—552.5	585—562.5	622.5—547.5	607.5—562.5
Orange-Yellow.	587.5—547.5	562.5—557.5	617.5—537.5	602.5—555
Yellow.	580—512.5	562.5—535	615—492.5	587.5—555
Yellow-Green.	565—497.5	535—525	580—480	555—530
Green.	542.5—492.5	530—507.5	570—480	537.5—517.5
Green-Blue.	525—472.5	512.5—495	550—447.5	525—502.5
Blue.	510—460	492.5—475	535—445	512.5—492.5
Violet.	482.5—432.5	470—462.5	497.5—430	475—455
Violet-Purple.	{ 687.5—665 485—440	462.5—455	{ 700—665 487.5—430	470—452.5
Purple.	{ 680—645 480—430		{ 680—635 497.5—430	475—460

smallest to the largest. For each of these transitions which were continuous we chose fifty stations for which we give the values in our tables and curves. Tables I, II, III and IV represent the tabulated results of all these experiments from the former point of view. These tables are constructed in an analogous manner to those of our former experiments. Tables I and II represent the "pleasant" combinations, and III and IV the "very pleasant." It must not be forgotten that we deal here as in our first article with highly saturated colours. Colours of high saturation are in themselves almost without exception agreeable, but their combinations, if not associated with particular objects, are neither pleasant nor unpleasant in the same degree as combinations in which one of the components is of lesser saturation. The present inquiry is therefore only one step in the desired direction. The investigation of the æsthetic value of binary and other combinations of less saturated colours, which will bear much more on the practical than does the subject of this discussion, is to follow.

RESULTS OF EXPERIMENTS.

In Table I the initial letters at the top in horizontal order represent the ground colours, red, orange-red, etc. Those at the left in vertical order represent the transmitted colours, the colours that were combined with the ground colour. Thus when red was the ground colour, it was chosen three times with orange-red and seven times with orange as a pleasant combination, as can be seen from Table I. Table III is analogous to Table I, representing the very pleasant combinations. In Tables I and III each of the sums of the vertical columns represents the total number of judgments of "pleasant" and "very pleasant" respectively when the colour at the head of the column was the ground colour, whereas the sums of the horizontal series give the total when the colour at the opposite end of the line (as transmitted colour) was combined with each of the others respectively. The number at the lower right-hand corner of each table gives the totality of the combinations selected. In Tables II and IV each of the numbers at the diagonal indicates the sum total of all the judgments for the

TABLE I.—PLEASANT COMBINATIONS

	R	O R	O	O Y	Y	Y G	G	G B	B	V	V P	P	
R		5	18	14	18	24	28	19	27	7	14	15	182
O R	3		12	8	16	23	24	21	17	16	11	10	163
O	7	5		4	9	15	26	23	22	18	11	12	146
O Y	10	5	1		6	12	17	16	2	16	11	12	133
Y	16	16	15	8		17	17	18	17	21	21	19	170
Y G	21	16	12	10	11		5	6	7	18	21	17	144
G	22	20	16	19	18	6		6	4	13	16	4	154
G B	22	21	18	17	21	7	8		1	7	13	18	147
B	13	18	18	17	26	8	8	2		8	7	14	135
V	19	16	17	16	18	18	18	6	6		3	11	145
V P	16	14	21	17	19	16	17	11	8	9		6	154
P	15	12	19	18	21	23	23	26	17	9	12		161
	163	142	162	148	177	172	169	181	137	187	141	14	1804

TABLE II.—PLEASANT COMBINATIONS.

R	O R	O O	V V G	G G B	B	V V P	P					
345	8	25	24	28	45	47	46	39	37	30	21	R
305	7	3	29	30	44	42	37	32	25	22		O R
308	5	6	27	30	41	40	35	32	31			O
281	17	20	30	33	37	32	28	30				O.V
348	28	33	35	39	39	40	39					V
317	41	46	45	33	37	40						V.G
323	9	7	25	33	37							G.
298	3	13	24	35								G.B
272	11	15	20									B
302	12	3										V
294	18											V.P
335												P
3728	2	1864										

TABLE III.—VERY PLEASANT COMBINATIONS.

	R.	O.R.	O.	O.V.	V.	Y.G.	G.	G.B.	B.	V.	V.P.	P.	
R		2	5	5	11	12	18	14	9	6	5	7	94
O.R.	0		4	3	11	11	16	11	10	6	6	4	82
O.	2	2		0	3	3	6	9	6	6	4	3	44
O.V.	1	1	1		1	6	4	6	3	6	2	5	36
V.	4	3	3	2		5	6	9	10	12	12	7	73
Y.G.	6	6	5	7	5		1	4	4	5	1	6	50
G.	10	7	6	5	6	2		2	0	4	3	3	48
G.B.	6	8	4	4	8	0	0		0	1	2	5	38
B.	6	8	4	5	9	0	0	0		1	2	4	39
V.	5	3	8	6	10	4	4	2	2		0	3	47
V.P.	2	0	5	4	9	7	5	3	2	2		1	40
P	3	1	5	10	15	12	13	8	9	9	4		88
	15	11	5	51	88	62	71	68	51	88	18	670	

R	OR	O	OY	V	YG	G	GB	B	V	VP	P
139	2	7	6	15	18	28	26	18	17	7	R
123	6	4	14	17	23	19	18	9	6	5	OR
94	1	6	8	12	13	10	14	9	7	6	O
87	5	13	9	10	8	12	6	18	17	7	OY
161	10	12	17	19	22	21	22	13	12	11	V
112	3	4	4	9	8	18	17	7	6	5	YG
121	2	5	7	16	15	14	13	12	11	10	G
106	10	5	5	13	12	11	10	9	8	7	GB
93	3	4	12	11	10	9	8	7	6	5	B
105	2	12	11	10	9	8	7	6	5	4	V
81	5	13	9	10	8	12	6	18	17	7	VP
136	10	12	17	19	22	21	22	13	12	11	P
1358	2	679									

colour at the head of the column and also at the right-hand end of the horizontal; for example, 345 in Table II indicates the sum total for all the judgments for the colour red.

In order that these results may be compared with those of the former experiments, they have likewise been expressed in curves with the series of colours in spectral order as the abscissa line and the frequency of their selection as ordinates. These curves are designated by Arabic numerals, and the letters *a b c*, in addition to the name of the respective colours to whose combinations the curves respectively refer. The lower curve in each case represents the "very pleasant" combination; the upper, the "pleasant" including the "very pleasant."

Curve 1 (*a*, *b*, and *c*) represents the results of all the combinations in which the colour red took part, Curve 2, those in which the colour orange-red took part, Curve 3, orange, etc.; *a* in each case represents the results when the colour indicated below was the ground colour, and corresponds thus to the vertical columns in Tables I and III; *b* on the other hand stands for the results when the colour indicated below, as transmitted colour, was combined with all the others, thus corresponding to the horizontal columns of Tables I and III. The height of the ordinates is taken from Tables I and III. Thus in Curve 1 (*a*), where red was the ground colour, it was chosen three times with orange-red, seven times with orange as a pleasant combination, when red was the transmitted colour (*b*) it was chosen five times with orange-red and eighteen times with orange as a pleasant combination. Finally *c* is the combination of the two, thus corresponding to the results in Tables II and IV.

In these experiments, as in our former ones, each colour appeared twice—in this case once as the ground colour and once as the transmitted colour. When the surfaces were of equal size and placed side by side as in the former experiments, the colours could unhesitatingly be combined; but in our present experiments, as can easily be seen, this could not be done, for when the colour appears as the ground colour it forms a border to the other, when it appears as the transmitted colour it is in the centre and the effect is quite different. Comparison of *a* and *b*

in this series of curves will show this difference. Consequently the c -curves are of relatively much less significance.

Curve 13 is a combination of all the curves. A represents that each of the colours below as ground colour was combined with all the others, and is therefore formed from the sums of the horizontal columns of Tables I and III respectively. B indicates that each of the colours below as transmitted colour was combined with all the others, and is therefore formed from the sums of the vertical columns of Tables I and III respectively. C represents a combination of a and b and is formed from Tables II and IV respectively, the ordinates corresponding to the sums which stand at the hypotenuse of the triangle.

In comparing these curves with those of the former experiments, we find the same general characteristics in spite of the great difference in the conditions. It must be noticed, however, that these characteristics cannot here be expected to be as marked as in the former case, since we now have only half the number of colours. In all those curves for orange and yellow we find the same broad, plateau-like shape. We find, too, that like those with which we are comparing them, these curves do not reach to so great a height as those expressing the other qualities. In many of the other curves we can trace a striking similarity with the curves of the former series, but it must not be forgotten that it would never be possible to trace all the prominences in these, on account of the smaller number of qualities, nor that the changed space conditions alone would prevent a complete analogy.

It is interesting to notice the difference in the maximum when the colour is the ground colour (a) and when it is the transmitted colour (b). In the curves for the "pleasant" in no case do these coincide except in that of green, where the maximum in both cases is as red. In the "most pleasant," however, there is a coincidence in the cases of red, green, blue, and violet-purple.

In this series of experiments as in the former it was not known until after the experiments were completed which of the colours used, if any, were complementary. It will be remembered that, in order to have each colour as free as possible from

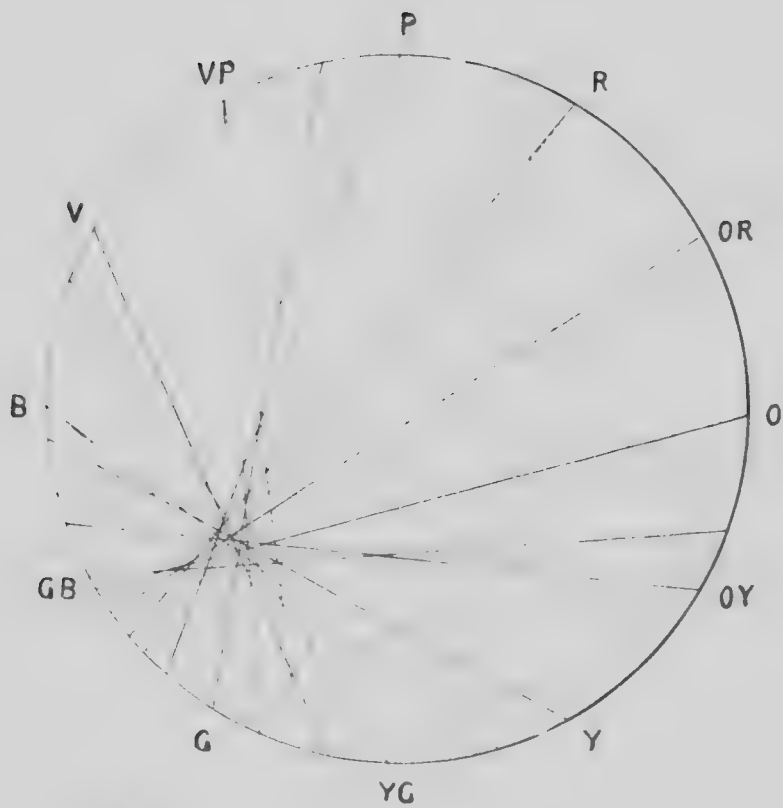


PLATE B



admixture with other colour tones, the colours used were obtained by illuminating pigment papers with light which had undergone a strong selective absorption. This made it impossible to get the complementary relation of these colours in the ordinary way, *i.e.*, by making colour equations as was done in the former experiments.¹ We have to thank Mr. A. H. Abbott, first assistant in the Psychological Laboratory, for the suggestion of the following method which was adopted. The upright blackened board, to which was attached the metal diaphragm, was replaced by another in which an opening of two and a half inches was made, and with which all other space relations were preserved. Now, by looking through the observing tube the transmitted colour can be seen as before. To the back of this upright board was attached a small electric motor to operate a rotation apparatus in front of the board. This latter makes it possible to rotate, as a kind of episcotister, sectors of any colour whose angular value could be varied between the limit of 10 and 360 degrees, the measurement to be obtained from a gradation at the periphery. When rotating we see the mixture of the colour of the rotating sectors and that transmitted through the aperture. Both colours are in the same illumination as in our trials; and if two of our colours were actually complementary we should, by varying the sectors of the rotating part (ground colour) till we reach colourless light as a result, be able to establish a complete colour equation. Unfortunately it was found that there was not a single pair of complementaries among our twelve colours, and since with our method it was not possible to mix more than two colours, we could only make out that the complementary of a certain colour was between two others and nearer to one than the other.

The complementary relation of the different colours as ascertained from the judgments of two observers will be found by examining the accompanying plate (B), which is made according to Table V. The fully drawn lines represent the results of observer K. Where observer A differed noticeably his decisions are indicated by dotted lines.

¹ See University of Toronto Studies, Psych. Ser., Vol. I, p. 241 No. IV.

TABLE V

Color	Observer K	Complementary Color	Observer A
Red	Between Green-blue and Green, nearer Green-blue.	Between Green-blue and Green, about midway	Green-blue and Green, much nearer Green-blue
Orange	Green-blue and Green, nearer Green-blue.	"	"
Yellow-green	Between Green-blue and Green, almost at Green-blue.	"	Green-blue and Green, very close to Green-blue.
Yellow	Between Green-blue and Green, nearer Green-blue.	"	Blue and Green-blue, nearer Green-blue.
Green	Between Green-blue and Green, nearer Blue.	"	Blue and Green-blue, nearer Blue.
Blue	Between Green-blue and Green, nearer Violet.	"	Violet and Blue, nearer Violet
Violet	Between Green-blue and Green, nearer Purple.	"	Purple and Violet-purple, somewhat nearer Purple.
Purple	Between Green-blue and Green, nearer Orange.	"	Orange-yellow and Orange, nearer Orange-yellow.
Orange-yellow	Between Green-blue and Green, nearer Yellow.	"	Yellow-green and Yellow, slightly nearer Yellow-green.
Yellow	Between Green-blue and Green, nearer Yellow.	"	Green and Yellow-green, much nearer Yellow-green.
Green-blue	Between Green-blue and Green, nearer Green.	"	Green and Yellow-green, about midway.
Blue	Between Green-blue and Green, nearer Green.	"	Green-blue and Green, nearer Green
Violet	Between Green-blue and Green, nearer Green.	"	"
Purple	Between Green-blue and Green, nearer Green.	"	"

It must be recalled from the spectroscopic analysis that our green-blue is by far more blue than green and that our blue is strongly on the violetish side somewhat like ultramarine in pigment colours.

TABLE VI.—MAXIMAL POINTS OF "PLEASANT."

Colour.	Number of Judgments.	Number of Judgments.	Colour.	Number of Judgments.
Pink	B.	23 G.	25 G.	47
Orange-red	G.-B.	21 G.	24 G.	44
Orange	V.-P.	21 G.-B.	23 G.-B.	41
Orange-yellow	G.	19 B.	20 G.&B.	36
Yellow	G.-B., B & P.	20 V. & V.-P.	21 V. P.	4
Yellow-green	R.	24 V.-P. & R.	21 R.	45
Green	R.	25 R.	22 R.	47
Green-blue	O.	23 R.	22 O.	42
Blue	O.	22 R.	23 O.	40
Violet	Y.	21 R.	19 Y.	39
Violet-purple	Y & Y.-G.	21 O.	21 Y.	40
Purple	Y.	19 Y.-G. & G.	23 Y.-G.	40

TABLE VII.—MAXIMAL POINTS OF "MOST PLEASANT."

Colour.	Number of Judgments.	Colour.	Number of Judgments.	Colour.	Number of Judgments.
Pink	G.	10 G.	18 G.		28
Orange-red	G.-B. & B.	8 G.	16 G.		23
Orange	V.	8 G.-B.	9 V.		14
Orange-yellow	P.	10 Y. G., G.-B. & V.	6 P.		15
Yellow	P.	15 V. & V.-P.	12 V. & P.		22
Yellow-green	P. & R.	12 O. Y.	7 P. & R.		18
Green	R.	18 R.	10 R.		28
Green-blue	R.	14 O.-R. & Y.	8 R.		20
Blue	O.-R. & Y.	10 Y.	9 O.-R. (18) Y.		19
Violet	Y.	12 Y.	10 Y.		22
Violet-purple	Y.	12 Y.	9 Y.		21
Purple	R. & Y.	7 Y.	15 Y.		22

In Tables VI and VII the reader will find the maximum values. By consulting Table V the complementary relations can be easily ascertained.

In considering the relation in which our results stand to the theory that the most agreeable combinations of red and with complementary colours, we shall classify them into groups as we did with the results of the former experiments. First, we find only a very few cases where we could say that the maximum might possibly coincide with the complementary colour. Thus, for instance, for orange-red whose complementary is between green-blue and green, but nearer to green-blue, we find the maximum for Curve *a*, "pleasant," at green-blue, while for the same curve, "most pleasant," it is decidedly nearer green-blue and blue, where is for the rest of the curves the maximum is to be found. The same is valid for the orange-yellow, which is at the curves how their maximum at the green-blue, which is the nearest to the complementary. Orange-yellow and yellow have also one maximum each, nearest to the complementary, but the latter yellow not an undisputed maximum, and the latter only in the combination Curve *c* for the "pleasant."

For the rest of the curves, one can say, like all the former, that somewhat approaching the complementary is the more agreeable, but nearer to the one which among an two wavelengths would be the nearest to the complementary. The difference we find throughout all the curves red in the maximum, while the complementary to green is beyond the range, towards violet-violet. In green-blue we find red and orange-blue the maximum, whilst the complementary is at orange-yellow. One must not be misled by the names of the colours. The green-blue of the former series was for no mean, where is now the green-blue of the present series of our former experiments, it is as the difference in the complementary shows. Therefore we find in two of the six curves a maximum further away from the complementary than the complementary, but there are always other maxima, as with the complementary system. Yellow has its maximum the nearest to the complementary system. For the rest, the maximum is further away from the complementary than the complementary.

does the maximum coincide with that one of our twelve qualities which is nearest to the complementary.

We see thus that the trials with spectrally pure colours essentially substantiate the results obtained with pigment colours. Although the two sets of experiments cannot be directly compared partly on account of the introduction of changed space relations, partly on account of the different choice and number of qualities, the trials with pure colours distinctly show again that the colour which has the preference is always one somewhat related to the complementary, but scarcely ever the latter itself. *Thus there is very little justification for the old dictum of the maximum pleasantness of pairs of complementaries.* Our experiments with pure colours make it evident also that the shape of the spatial space relations of the components have a great influence. The detailed report of this phase of our results will appear in a third article.

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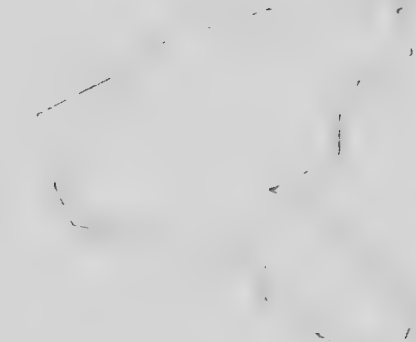
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R OR O OY Y VC C CB B V VP P R



R OR O OY Y VC C CB B V VP P R

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R OR O OY Y VC C CB B V VP P R



RFD

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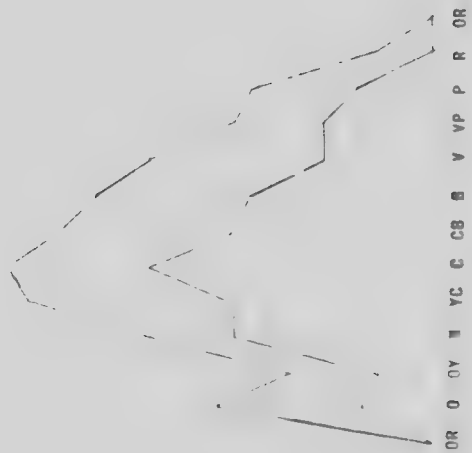
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OR O OY Y YC C CB B V VP P R OR



OR O OY Y YC C CB B V VP P R OR

ORANGE RED

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OR O OY Y YC C CB B V VP P R OR

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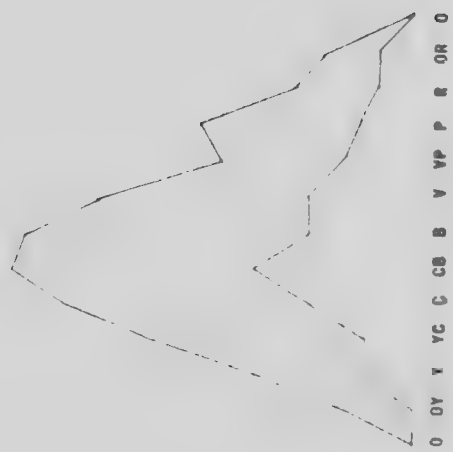
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O OY Y YC C CB B V VP P R OR B



ORANGE

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O OY Y YC C CB B V VP P R OR O



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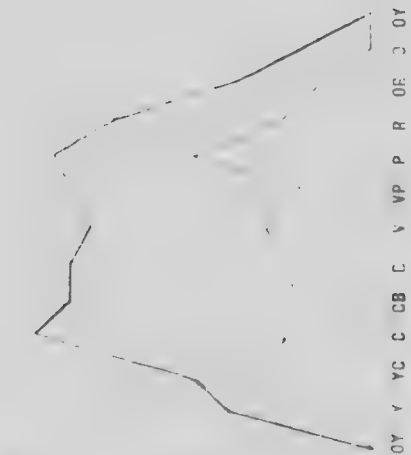
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ORANGE BELLOW

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Y YC C CB B V VP P R OR O OY Y



Y YC C CB B V VP P R OR O OY Y

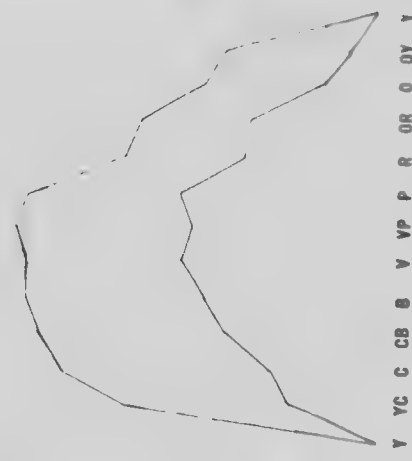
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Y YC C CB B V VP P R OR O OY Y

YELLOW

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VC C CB B V VP P R OR O OY Y VC



VC C CB B V VP P R OR O OY Y VC



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VC C CB B V VP P R OR O OY Y VC



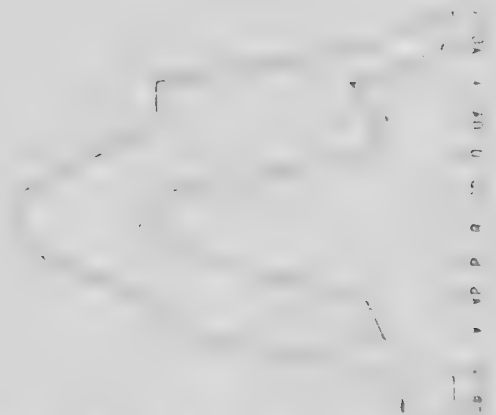
YELLOW GRIP

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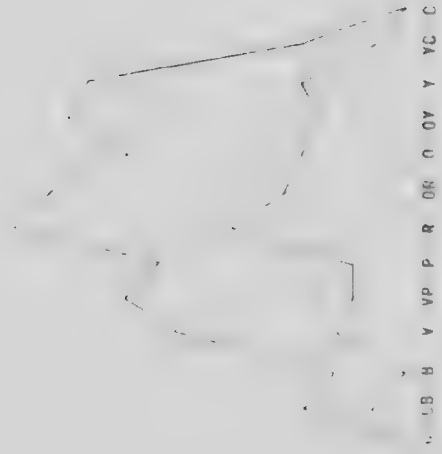
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V VP P B O OY Y VC



V VP P B O OY Y VC

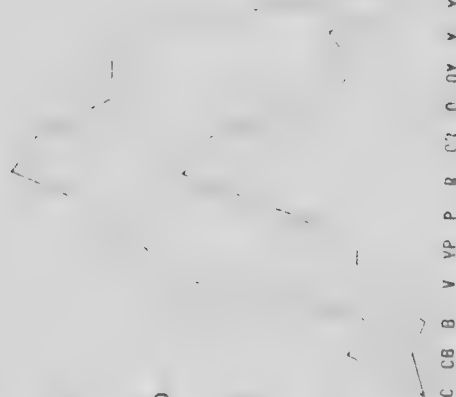
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C CB B V VP P R OY OY Y YL C

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CB B V VP P R OR O OY Y YC C CB

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CB B V VP P R OR O OY Y YC C CB



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B V VP P R OR O OY Y YC C CB B



B V VP P R OR O OY Y YC C CB B



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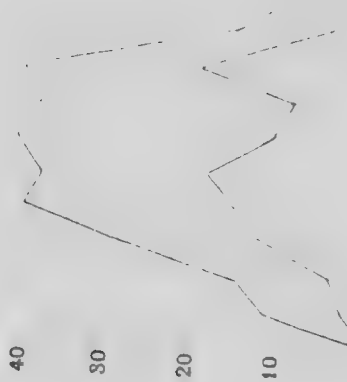
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B V VP P R OR O OY Y YC C CB B



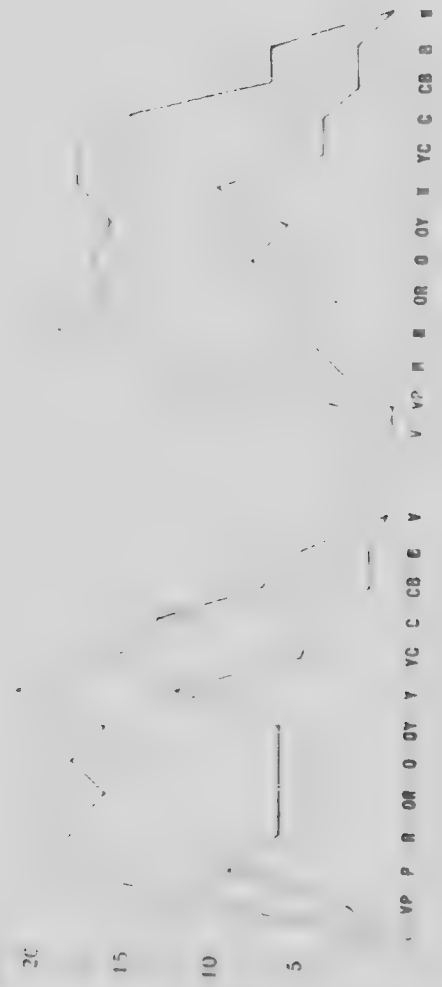
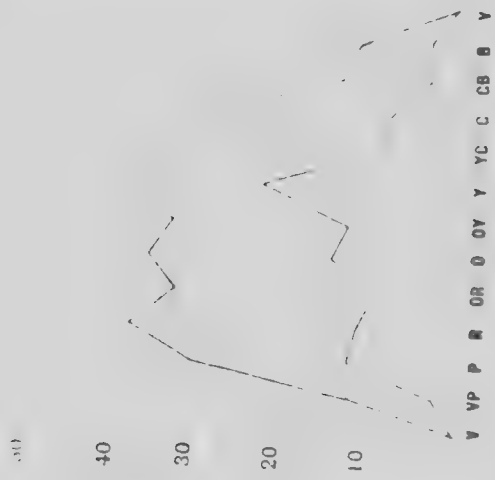


Figure 1

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VP P R OR O DY V YC C CB B V VP



VP P R OR O DY V YC C CB B V VP

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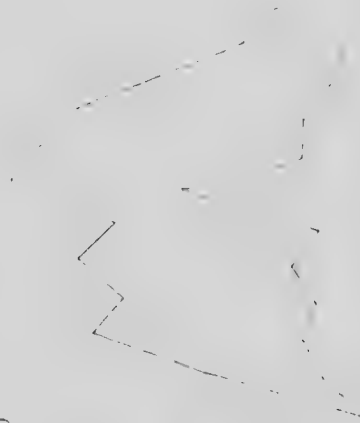
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VP P R OR O DY V YC C CB B V VP



VIOLET PURPLE

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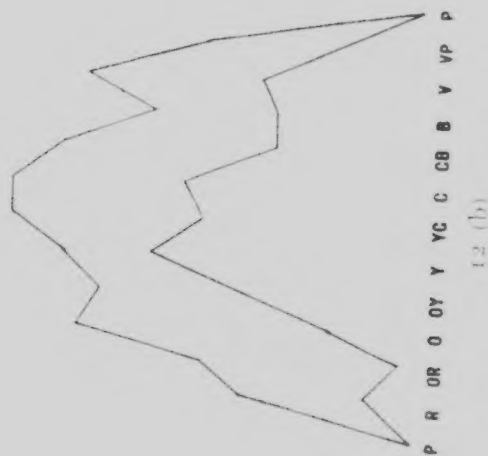
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12 (a)



12 (b)

P-R-P-L-E

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12 (c)

200



200



400



300

100



100



200



100

R OR O OY Y VC C CB B V VP P R
13 (a)

R OR O OY Y VC C CB B V VP P R
13 (b)

R OR O OY Y VC C CB B V VP P R
13 (c)

COMBINATION-CURVE